Assessing the Effects of Instrument Systematic Uncertainty in the IR Measurements on Derivation of Spectral Fingerprints Temperatures

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Agenda

- Background/Objectives
- Detail Analysis
  - Input definition
  - Method
  - Output
- Conclusion
- Next Steps

Background

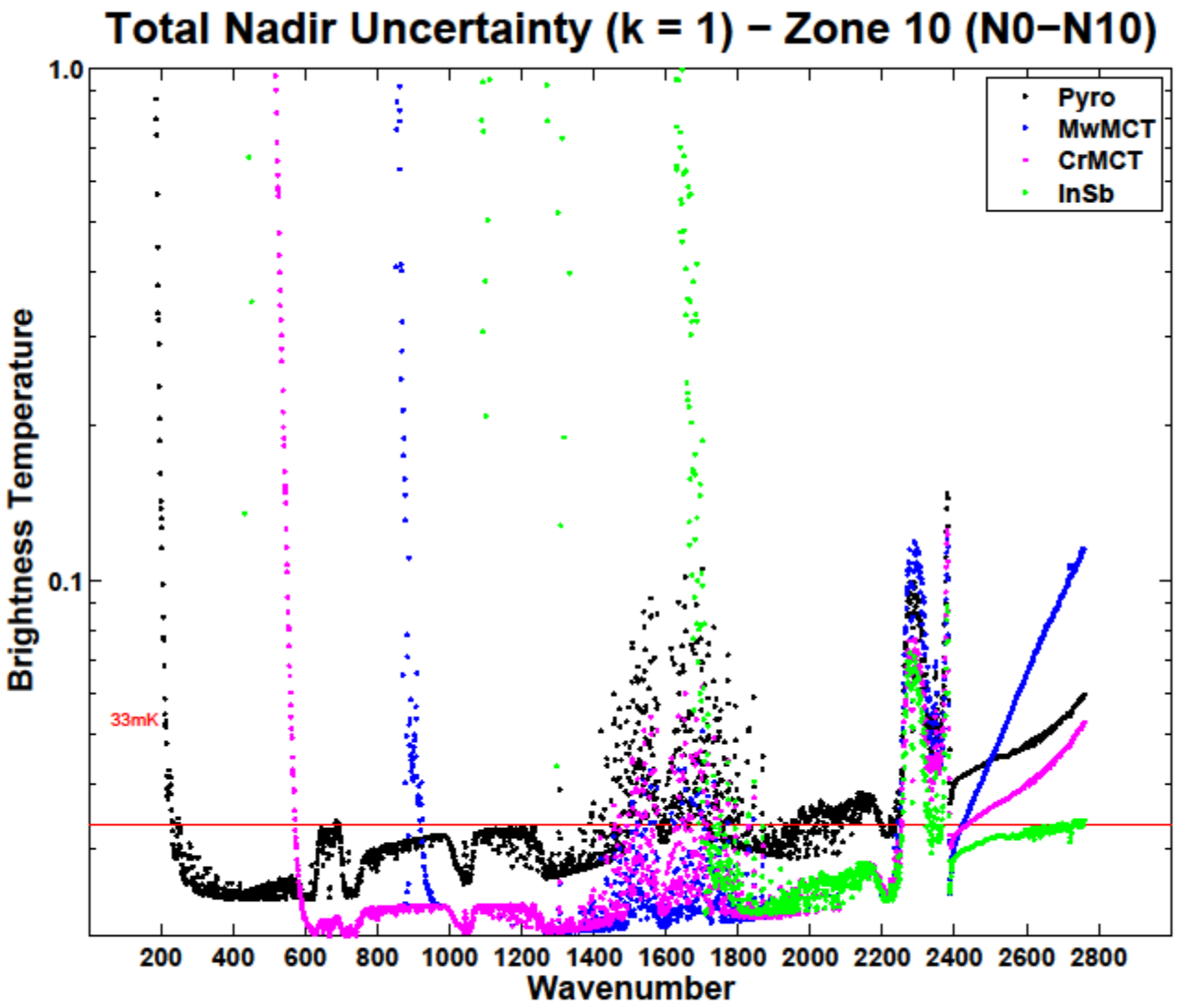
- Continuous work on determining an allowable IR systematic uncertainty distribution across the 200-2000 (cm-1) wavenumbers and scene temperatures of 200-300K that will still enable the derivation of physical parameters.
- Unrealistic IR systematic uncertainty was used in the previous work.

Objectives

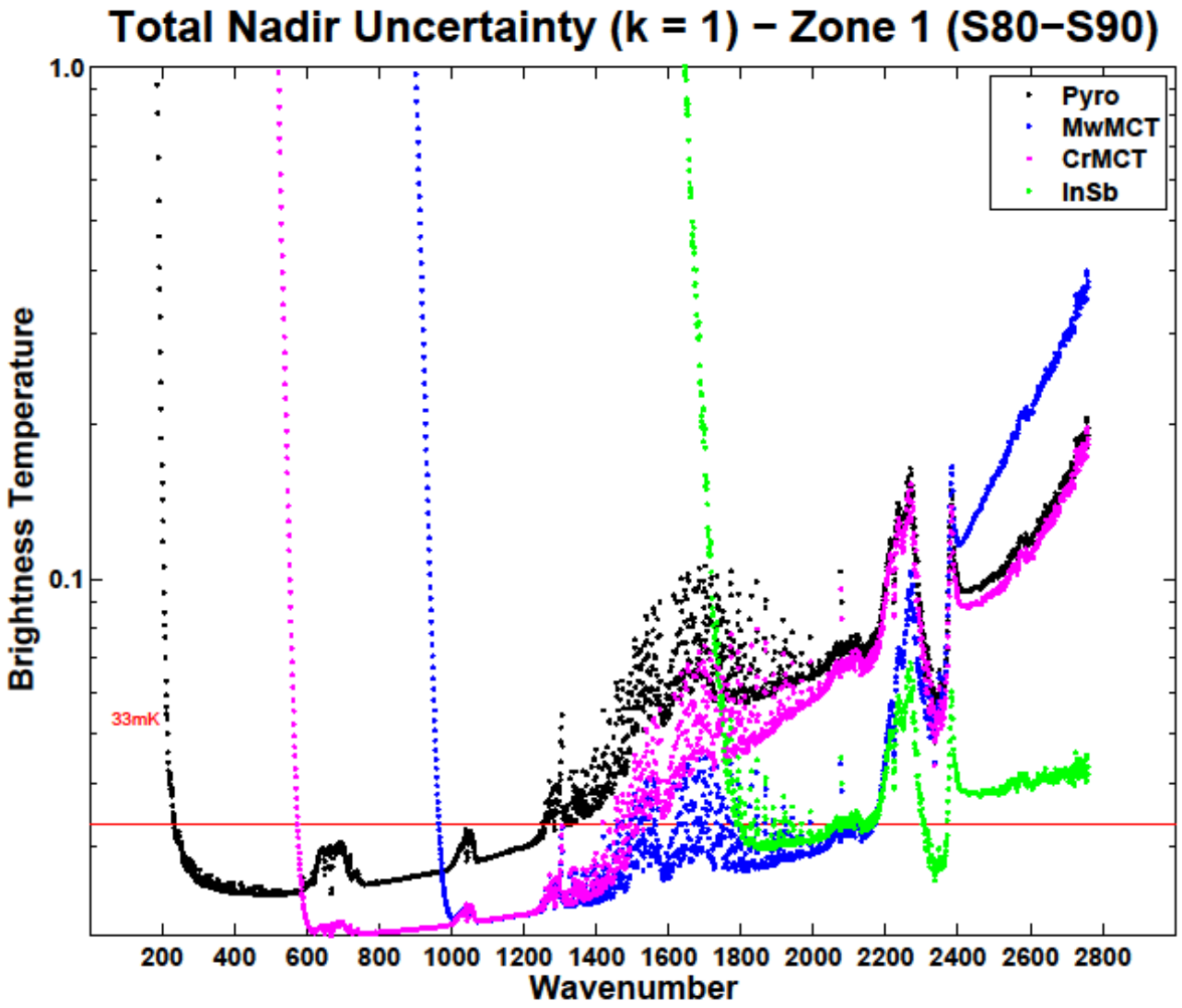
- To assess the effects of the realistic IR systematic uncertainty on the derivation of spectral fingerprints.
- Ultimately, to help in a what-if study on the IR uncertainty requirement effects on the fingerprint derivation.

Current Study

- Inputs
  - Datasets: the radiance differences of all-sky CCCMA from Huang et al. [2010].
  - Instrument bias function: IR instrument systematic uncertainty model from Dave Johnson by using scene temperatures from Seiji's TB zonal annual averages.
  - Baseline (no bias) instrument
    - To study a 10-year expected change, the radiance difference is decreased by a factor of 10.
  - CLARREO instrument
    - Ensembles of IR bias were simulated and added to the baseline data.
- Method - Huang et al. [2010]
- Outputs - Performance measures of % detection.



Three detectors were selected:
-a pyroelectric detector (Pyro) to cover 200-700 cm-1
-a longwave (LW) HgCdTe detector (CrMCT) to cover 600-1400 cm-1
-a midwave (MW) HgCdTe detector (MwMCT) to cover 1000-2000 cm-1.



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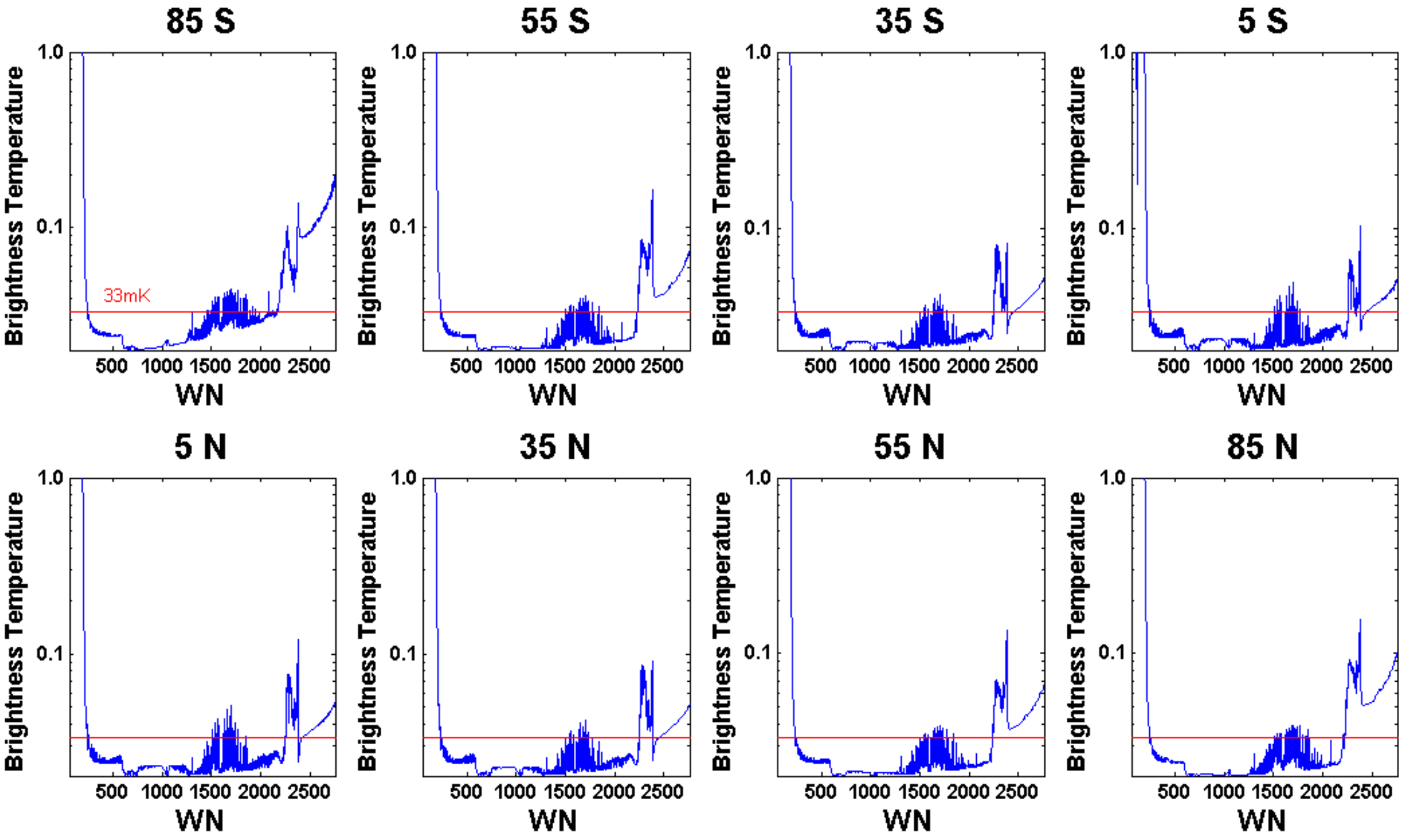
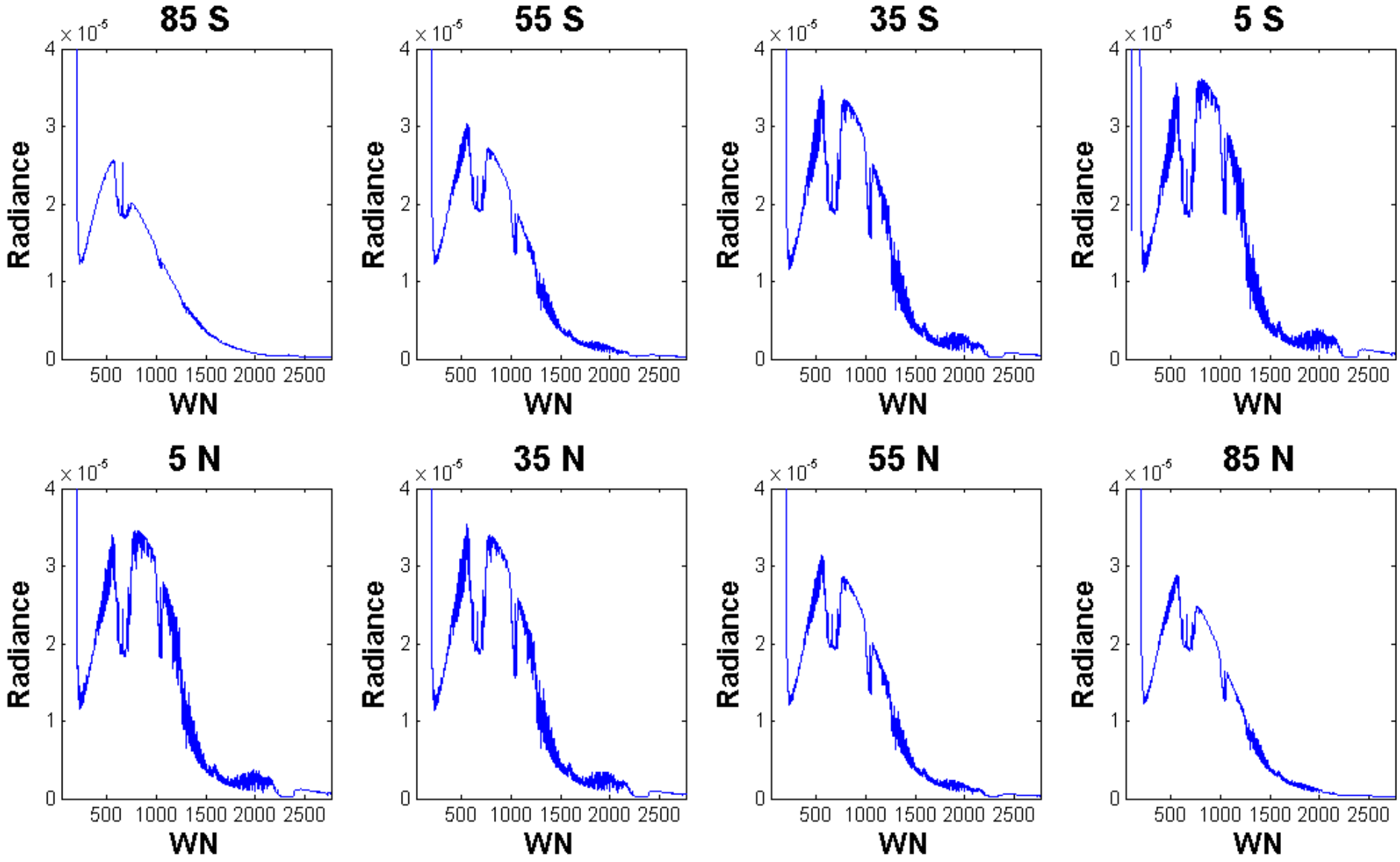
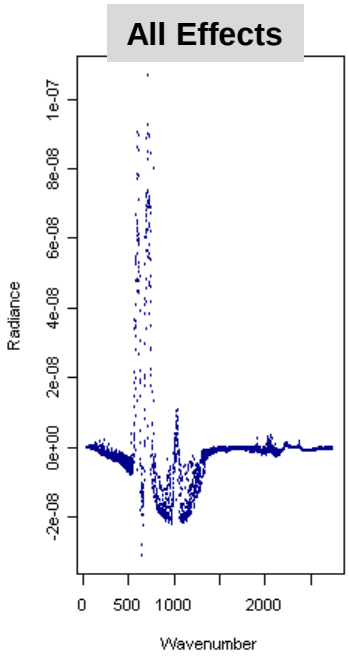
Current Instrument Bias (k=1)

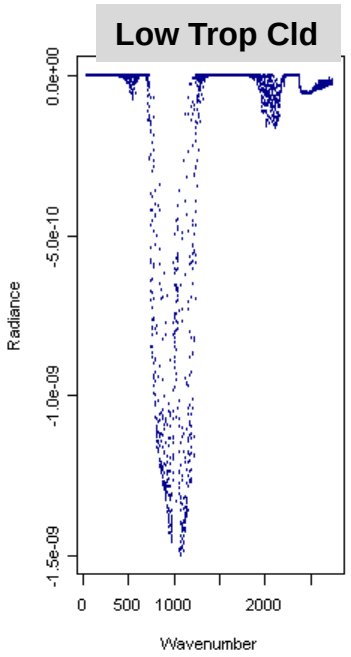


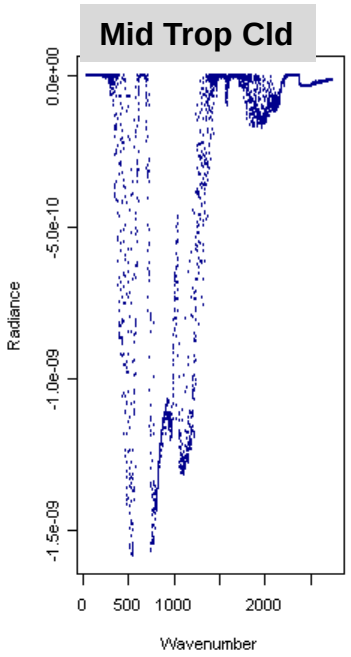
Current Instrument Bias (k=1)

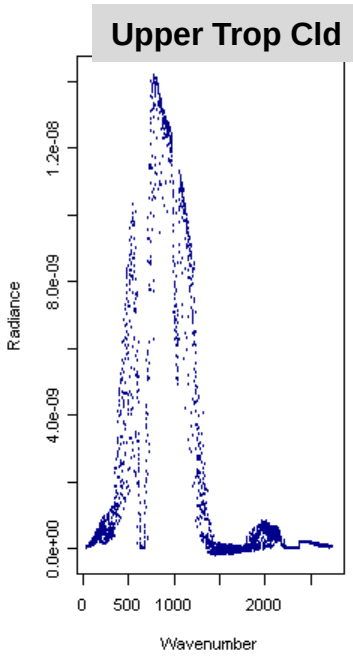


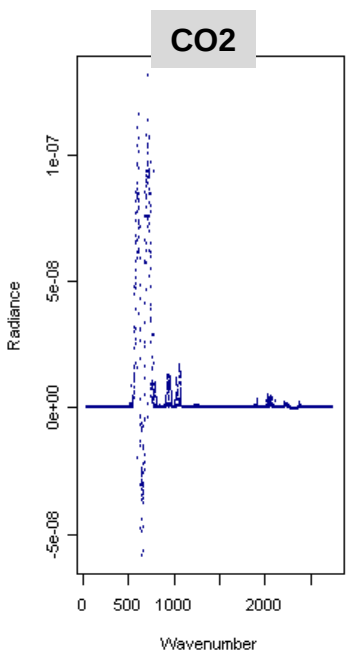
Signal Signatures – CCCMA model from Huang et al. [2010].

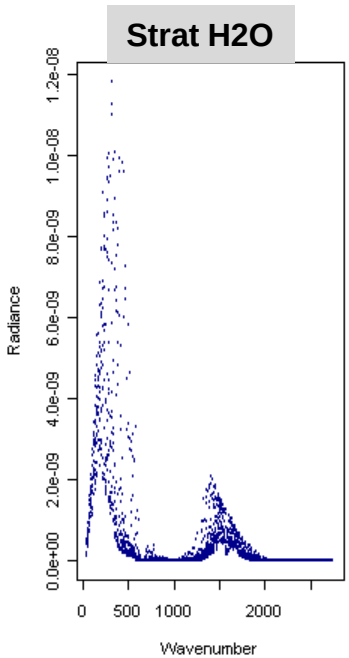


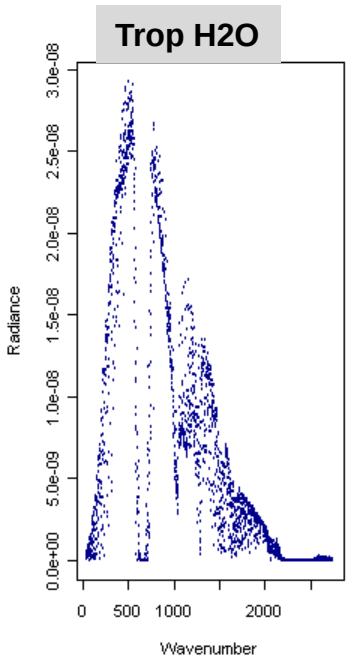


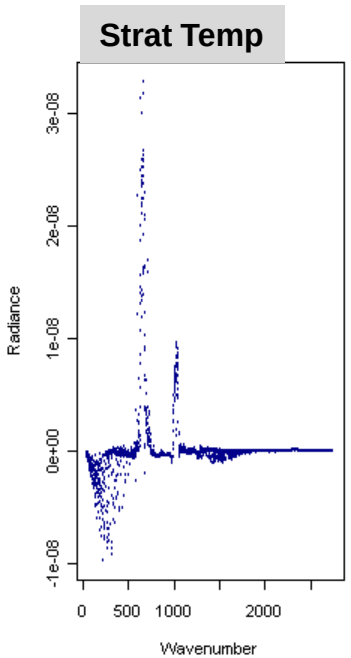


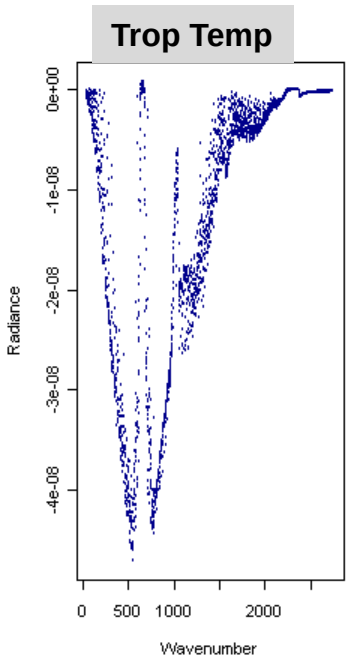


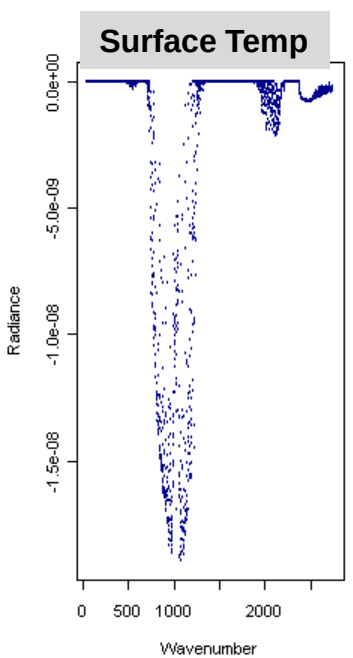








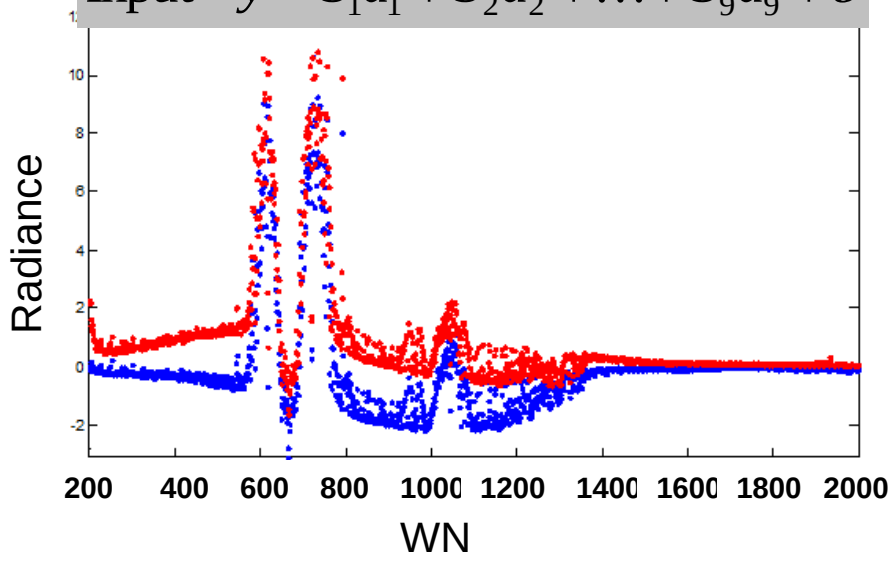




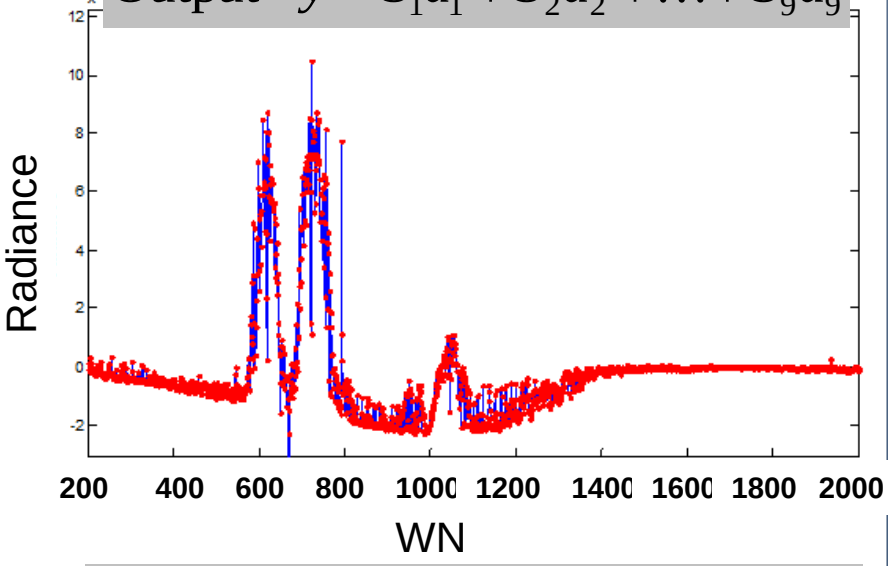
Fingerprint Example: All effects of Zone 10

(Blue = No Bias, Red = CLARREO)

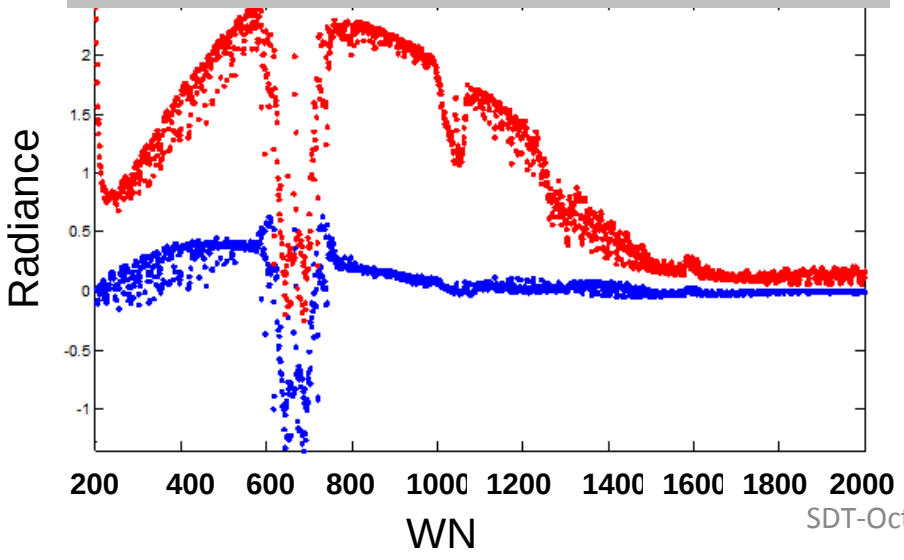
Input $y = S_1 a_1 + S_2 a_2 + \ldots + S_9 a_9 + \varepsilon$



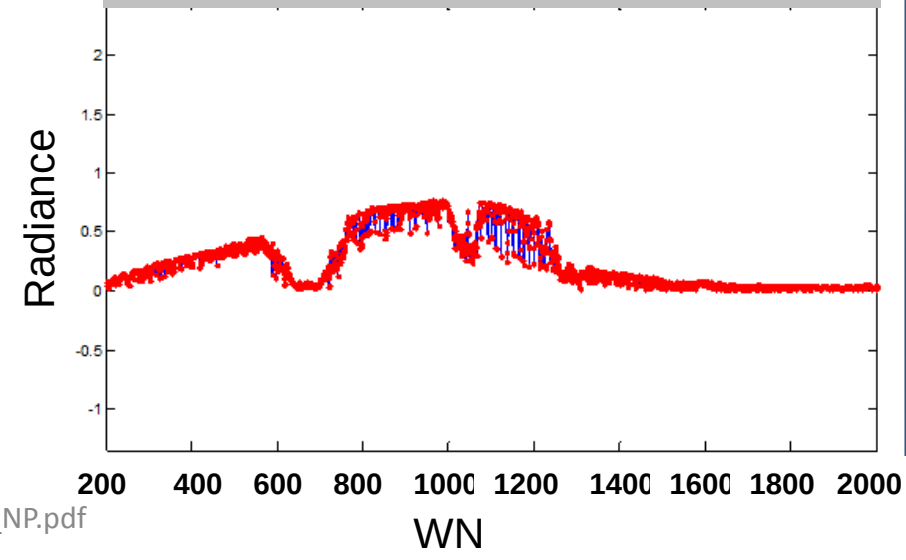
Output $\hat{y} = S_1 \hat{a}_1 + S_2 \hat{a}_2 + \ldots + S_9 \hat{a}_9$



Fitting Error (FE) = Input - Output = ε



Retrieval Uncertainty (RU) = $U(\hat{y})$



Fingerprint Uncertainty

Fitting Error

- Potential causes:
  - – Missing nonlinearity of atmospheric effects.
  - – Missing vertical resolution of atmospheric effects.
  - – Missing atmospheric properties (e.g., cloud optical thickness, cloud height, cloud fraction, etc.)
  - ? Other unknown

Retrieval Uncertainty

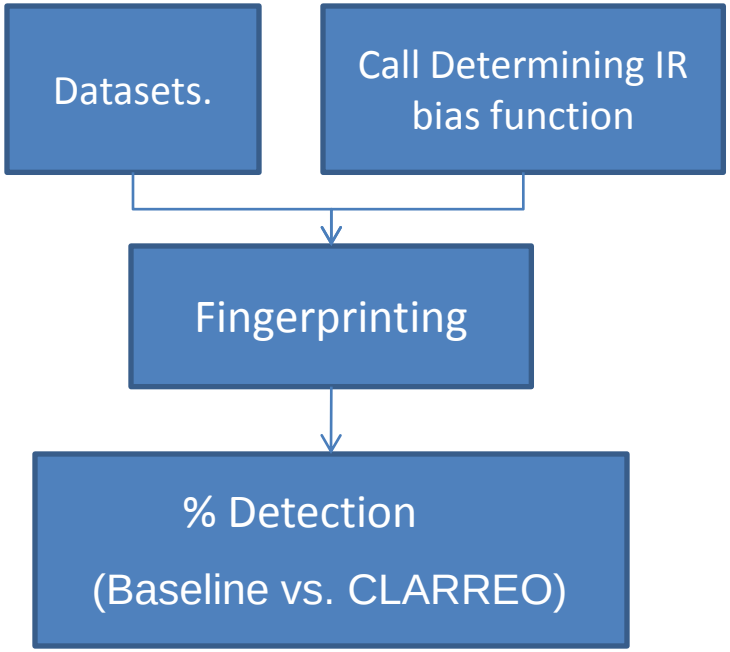
- Potential causes:
  - + Highly spectral, spatial, and temporal correlated data.
  - + High natural variability.
  - + High signal shape uncertainty.
  - + Missing atmospheric effects in the analysis.
  - ? Other unknown

How ensembles of bias function were obtained?

Let N = Number of Simulation

$RN_{N\times 6}$ = randn(0,1)

For i = 1 to N



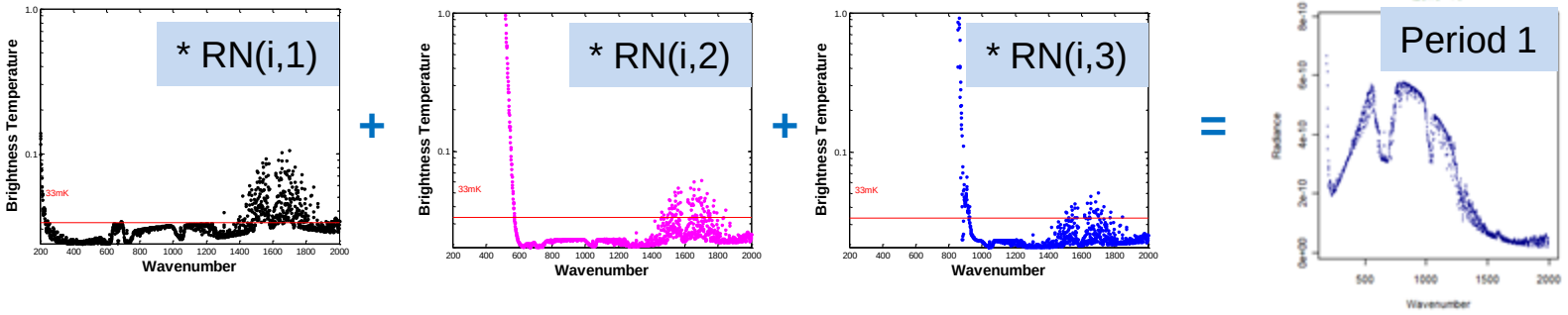
End

where % Detection = % of Number of Signal ≥ Threshold

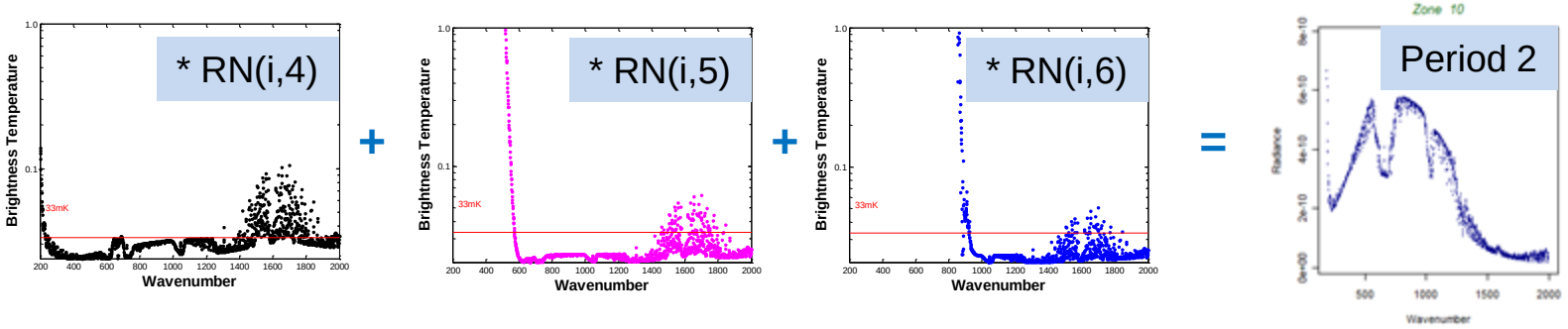
Determining IR Bias Function

For simulation run ith,

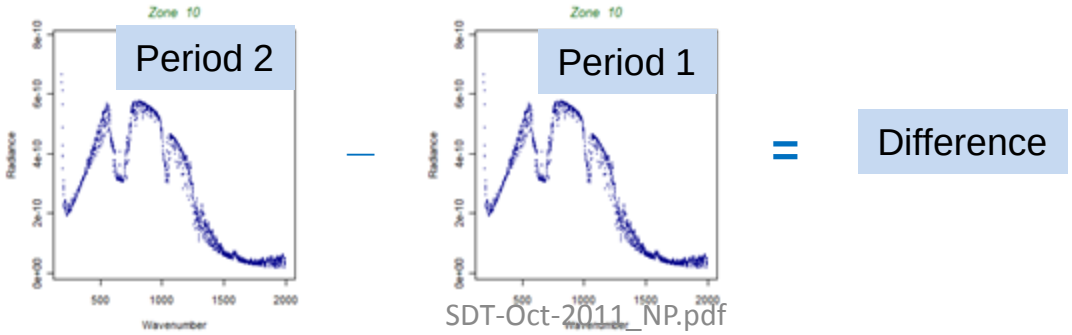
Period 1:



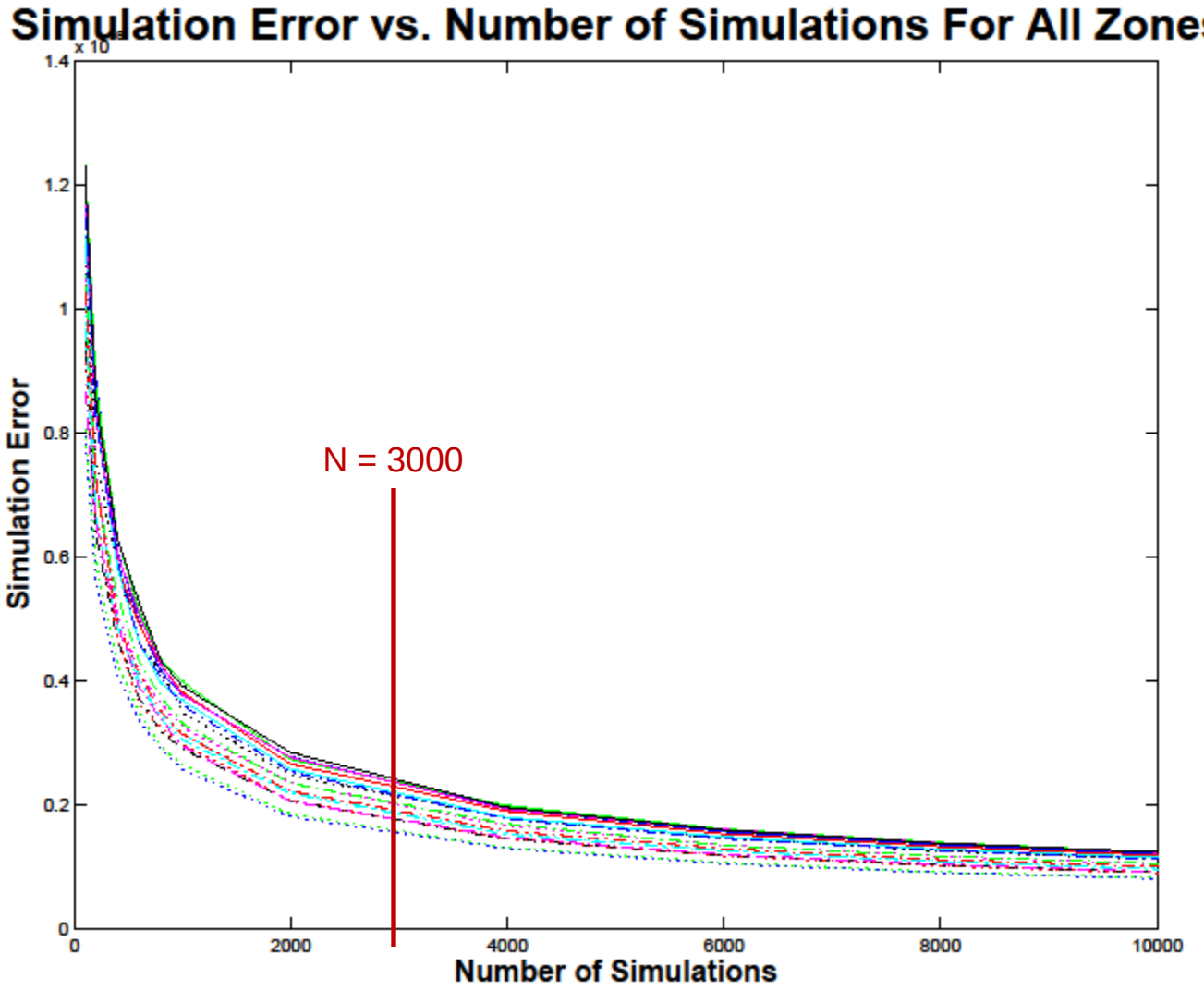
Period 2:



Difference:



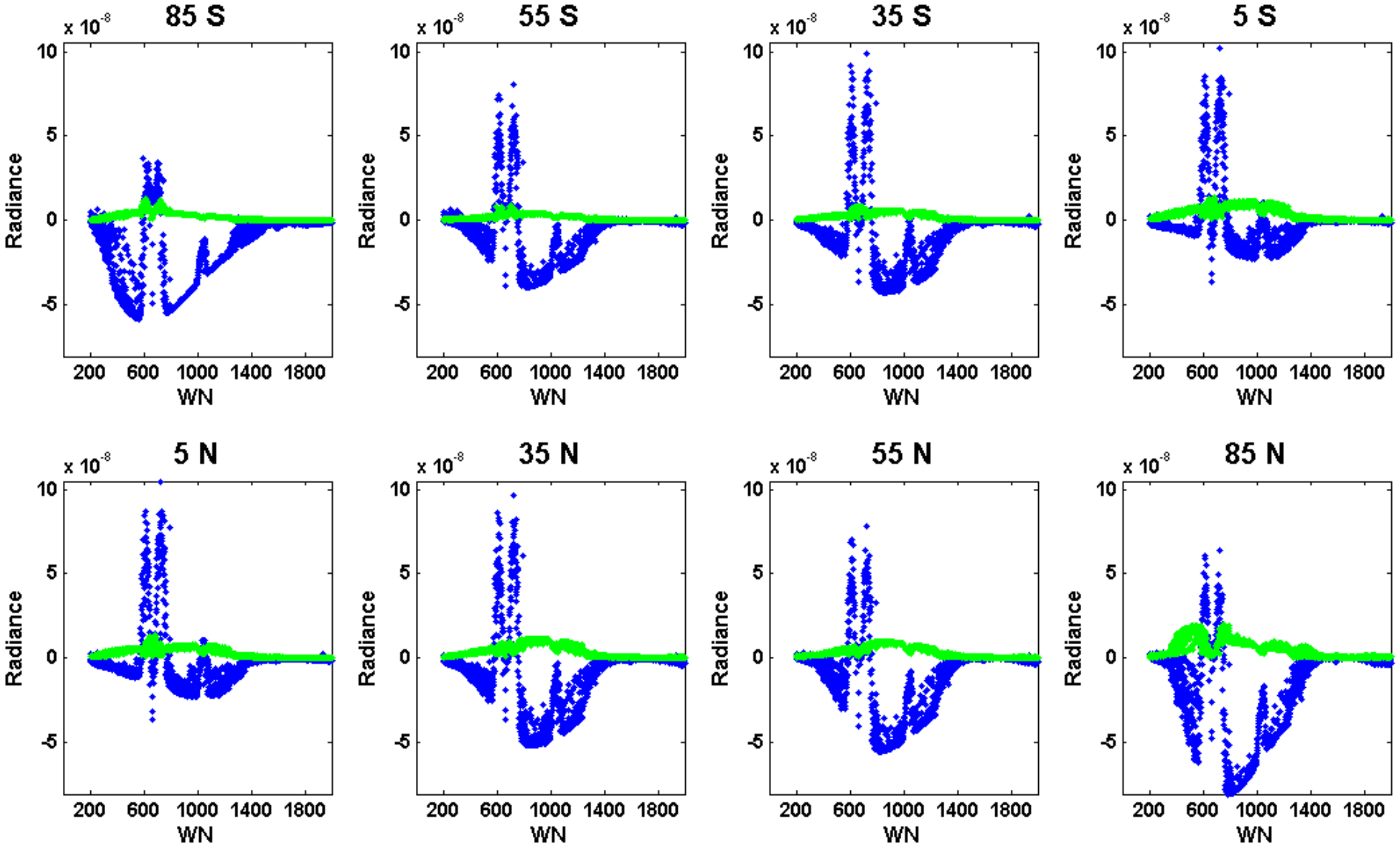
How many simulations (N)?



SDT-Oct-2011_NP.pdf

Perturbed all effects – No Bias Baseline

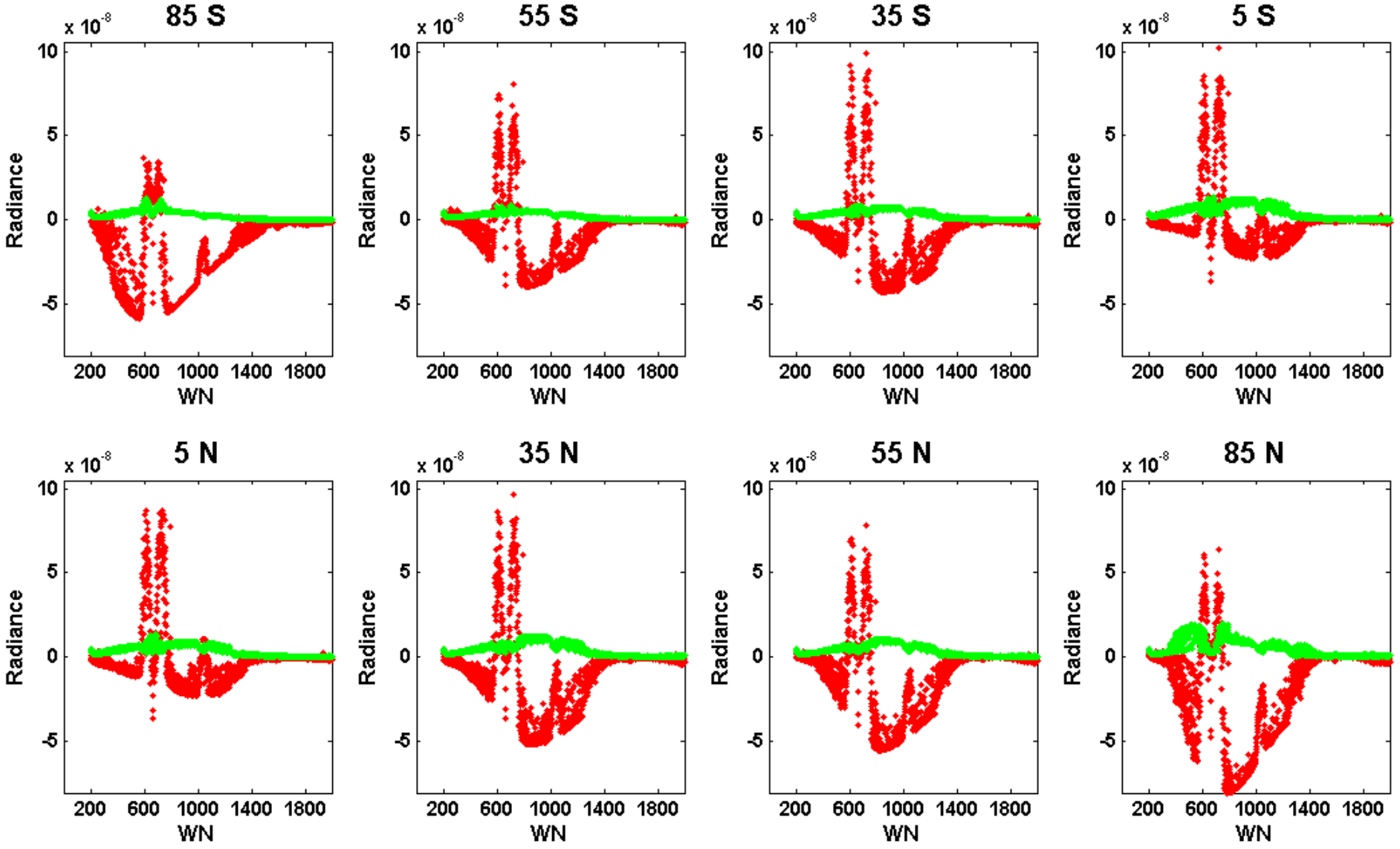
(Blue = Retrieval Mean of No Bias Baseline, Green = Fingerprint Uncertainty)



Define: Signal(No Bias) = Retrieval Mean of No Bias / Fingerprint Uncertainty of No Bias

Perturbed all effects - CLARREO

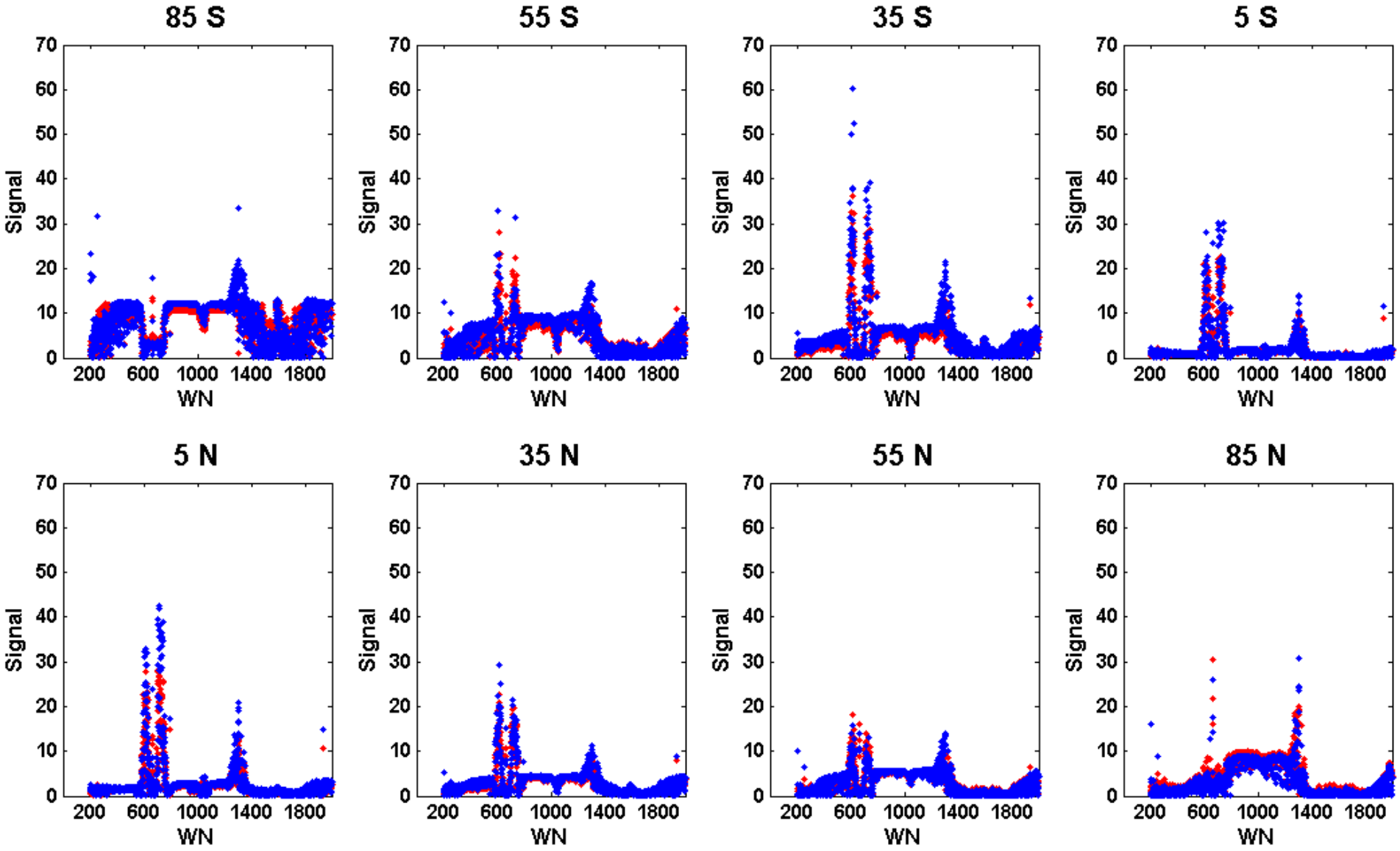
(Red = Retrieval Mean of CLARREO, Green = Fingerprint Uncertainty)



Define: Signal(CLARREO) = Retrieval Mean of CLARREO / Fingerprint Uncertainty of CLARREO

Perturbed all effects – No Bias Baseline vs. CLARREO

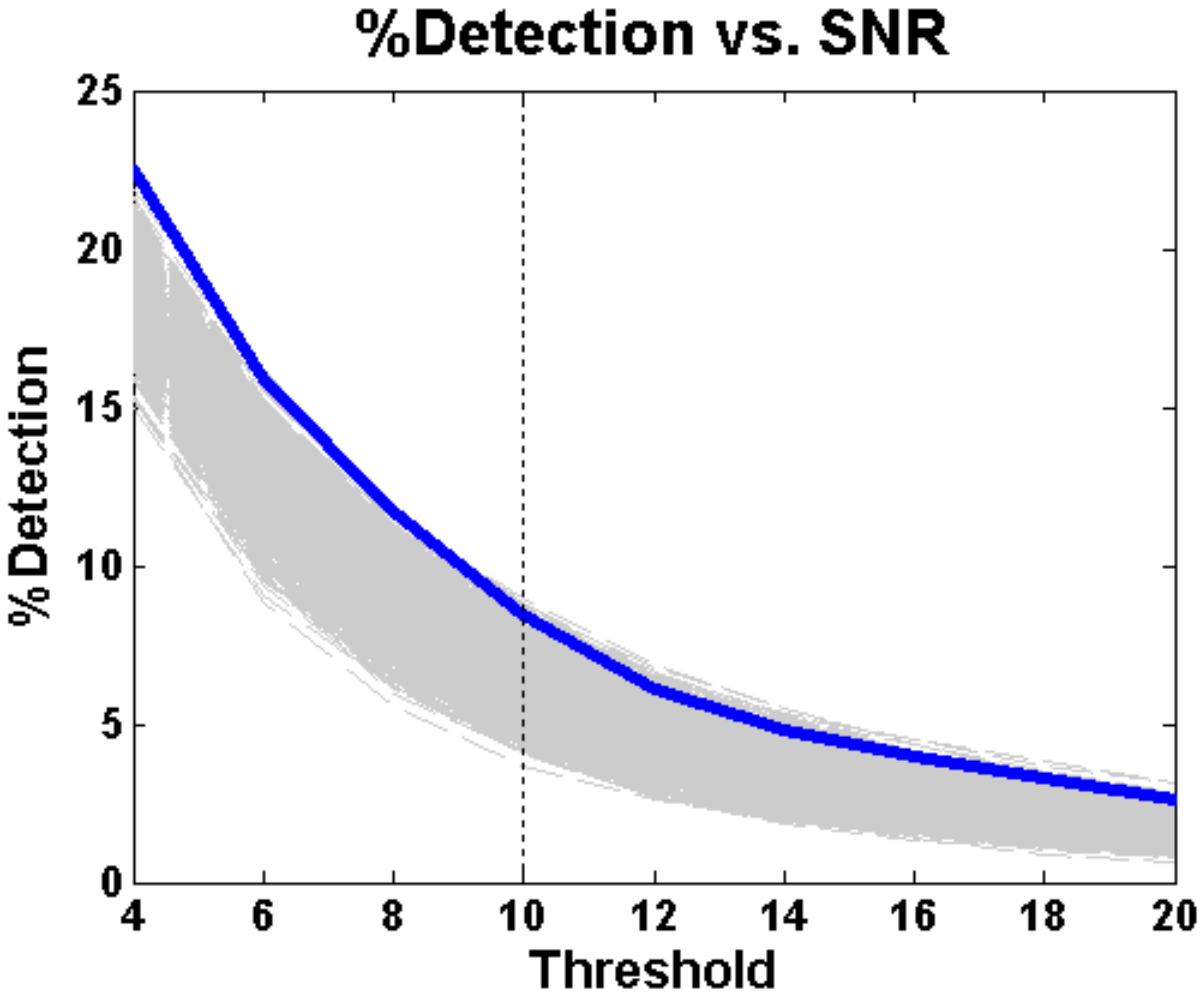
(Blue = Signal of No Bias, Red = Signal of CLARREO)



Define: % Detection = Relative volume of signals that are at least the specified threshold

% Detection Comparison

Blue = No Bias; Gray = Ensembles of CLARREO



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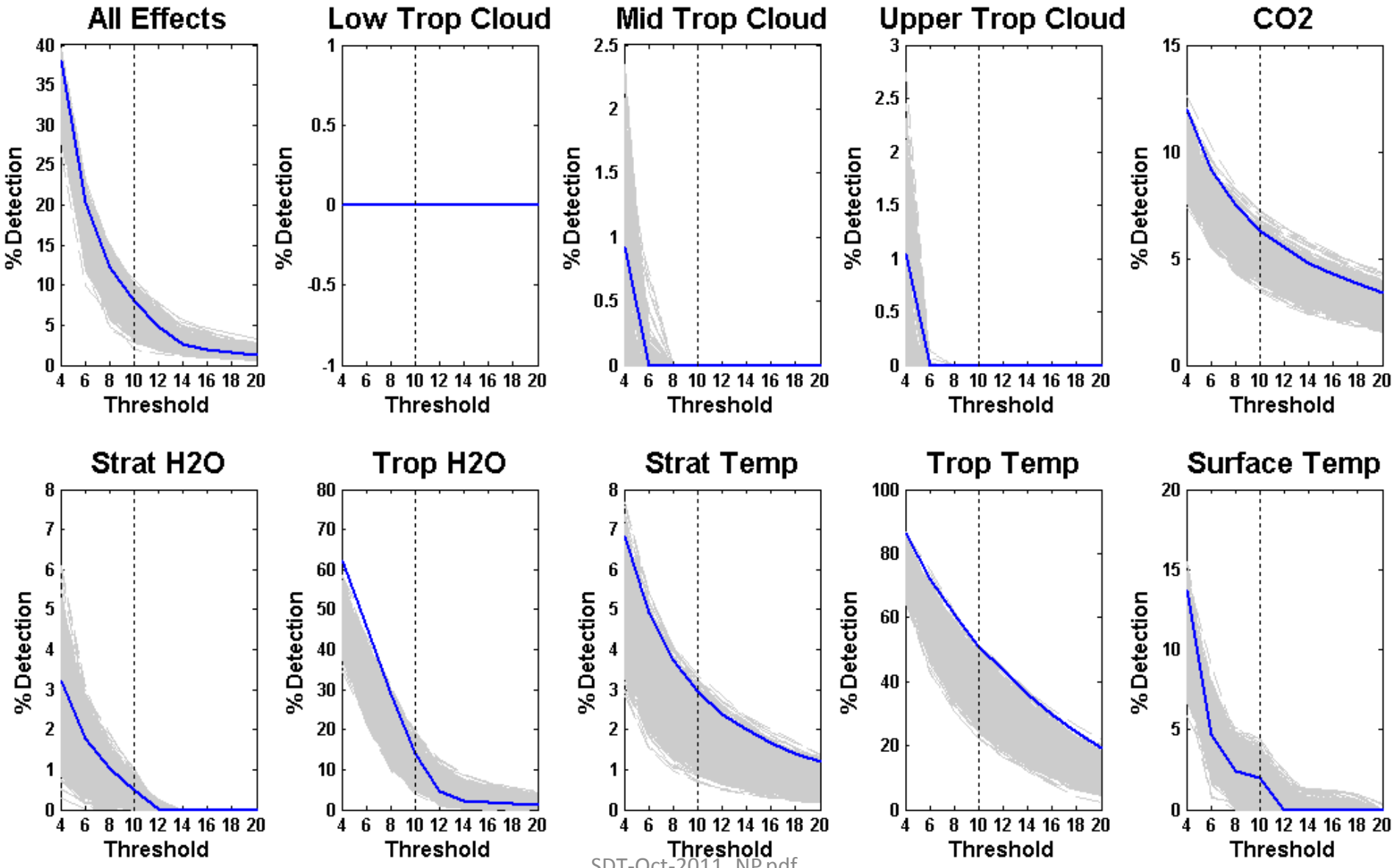
%Detection by Effects (all zones combined)

Blue = No Bias; Gray = Ensembles of CLARREO



Conclusion/Next Steps

We have demonstrated a framework of applying fingerprinting (based on Huang et al. [2010]) to assess the effects of the realistic IR systematic uncertainty on the derivation of spectral fingerprints.

Next Steps

- Counter-intuitive on Retrieval Uncertainty (RU) is much smaller than the Fitting Error (FE).
  - Are we underestimating the RU?
  - Are we under-fitting (left out) atmospheric effects?
  - Or both?
- Try with a comprehensive and continuous climate dataset (multiple years, multiple vertical resolutions, etc.)